The Neutron Charge Form Factor at Low Q^2

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Abstract. Measurement of the charge form factor of the neutron G_E^n presents a sensitive test of nucleon models and QCD-inspired theories. In particular, the pion cloud is expected to play a dominant role in the low-momentum transfer region of G_E^n. At the MIT-Bates Linear Accelerator Center, G_E^n has been measured by means of *(e,e'n)* quasielastic scattering of polarized electrons from vector-polarized deuterium. The experiment used the longitudinally polarized stored electron beam of the MIT-Bates South Hall Ring along with an isotopically pure, highly vector-polarized internal atomic deuterium target provided by an atomic beam source. The measurements have been carried out with the symmetric Bates Large Acceptance Spectrometer Toroid (BLAST) with enhanced neutron detection capability. From the beam-target double polarization asymmetry with the target spin oriented perpendicular to the momentum transfer the form factor G_E^n is extracted over a range of four-momentum transfer Q^2 between 0.12 and 0.70 $(\mathrm{GeV/c})^2$ with minimized model dependencies.

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INTRODUCTION

The electromagnetic form factors of the nucleon provide basic information on nucleon structure. At low momentum transfer, the pion cloud of the nucleon is expected to play a significant role in the quantitative description of the form factors, in particular for the electric form factor of the neutron G_E^n in the absence of a net charge. Thus, the low-Q^2 region of G_E^n is an ideal testing ground for QCD- and pion-cloud inspired and other effective nucleon models. Among the four non-strange nucleon electromagnetic form factors, the electric form factor of the neutron G_E^n is experimentally the least known one with uncertainties of typically 15-20 %. Significant improvement of the experimental uncertainty is highly desirable and is setting strong constraints for nucleon models. A precise knowledge of G_E^n at low Q^2 is also essential to reduce the systematic errors of parity violation experiments. In recent years the advent of polarized beams and targets have contributed to minimize both the systematic errors and the model dependency. This work reports about a new measurement of G_E^n over a range of four-momentum transfer Q^2 between 0.12 and 0.70 $(\mathrm{GeV/c})^2$ with the BLAST experiment at the MIT-Bates Linear Accelerator Center. The technique makes use of *(e,e'n)* quasielastic scattering of polarized electrons from vector-polarized deuterium.

THE BLAST EXPERIMENT

The BLAST experiment has been designed to measure spin-dependent electron scattering at intermediate energies from polarized targets in the elastic, quasielastic and resonance region. Based on the internal target technique BLAST optimizes the use of a longitudinally polarized electron beam stored in the South Hall Ring of the MIT-Bates Linear Accelerator Center, in combination with an isotopically pure, highly-polarized internal target for both hydrogen or deuterium. In case of deuterium the target was both vector and tensor polarized. The polarized target is provided by an atomic beam source (ABS). The polarized atoms are injected into a 60 cm long cylindrical target cell with open ends through which the stored electron beam passes. As there are no target windows the experiment is very clean with negligibly small background rates of only a few percent in the prominent channels.
The direction of the target spin can be freely chosen within the horizontal plane using magnetic holding fields. During BLAST data taking, the spin direction pointed at 32^o and 47^o to the left side of the beam axis in the 2004 and 2005 runs, respectively. At Bates beam currents of up to 225 mA were stored in the ring at 65% polarization and beam lifetimes of 20-30 minutes. The electron beam energy was 850 MeV throughout the BLAST program. The relatively thin target in combination with the high beam intensity yields a luminosity of about 5×10^{31} $cm^{-2}s^{-1}$ at an average current of 175 mA.
The BLAST detector is a toroidal spectrometer consisting of eight normal-conducting copper coils producing a maximum field of 3800 G. The two in-plane sectors opposing each other are symmetrically equipped with drift chambers for the reconstruction of charged tracks, aerogel-Cerenkov detectors for e-π discrimination and 1" thick plastic scintillators for timing, triggering and particle identification. The angular acceptance covers scattering angles between 20^o and 80^o as well as $\pm15^o$ out of plane. The symmetric detector core is surrounded by thick large-area walls of plastic scintillators for the detection of neutrons using the time-of-flight method. The thin scintillators in combination with the voluminous wire chambers in front of the neutron detectors were used as a highly efficient veto for charged tracks, making the selection of *(e,e'n)* events extremely clean. The setup allows to simultaneously measure the inclusive and exclusive channels *(e,e')*, *(e,e'p)*, *(e,e'n)*, *(e,e'd)* elastic or quasielastic, respectively, as well as *(e,e'π)* in the excitation region of the Δ-resonance.

PRELIMINARY RESULTS

The experimental double spin asymmetry is formed from the measured *(e,e'n)*-yields in each beam-target spin state combination, properly normalized to the collected deadtime-corrected beam charge. For five bins in Q^2, the experimental asymmetry as a function of missing momentum is compared with the full BLAST Montecarlo result based on deuteron electrodisintegration cross section calculations by H. Arenhovel [1] with consistent inclusion of reaction mechanism and deuteron structure effects. The electric form factor of the neutron is varied as an input parameter to the Montecarlo simulation and its measured value is extracted by a chi-square minimization for each Q^2 bin.

Fig. 1 shows the preliminary result for G_E^n from the 2004 run of BLAST along with the world data from polarization experiments [2]. Also shown is the parameterization by Galster [3]. The excess of the data over the Galster curve at high and at low Q^2 is better accounted for by the more recent parameterization by Friedrich and Walcher [4] (FW), who describe all four nucleon form factors as sums of a smooth and a bump part, where the latter is attributed to the role of the pion cloud around the nucleon. The new preliminary BLAST data are quite consistent with both the bulk of existing data as well as with the parameterizations shown in Fig. 1, of which FW parameterization appears slightly favored. Note that the BLAST data are preliminary and based on only about half of the statistics that were acquired in the total run in 2004 and 2005. The preliminary results shown here comprise parts of a PhD thesis [5] based on the BLAST data taken in 2004. Analysis of the full 2004-2005 dataset is in progress [6].

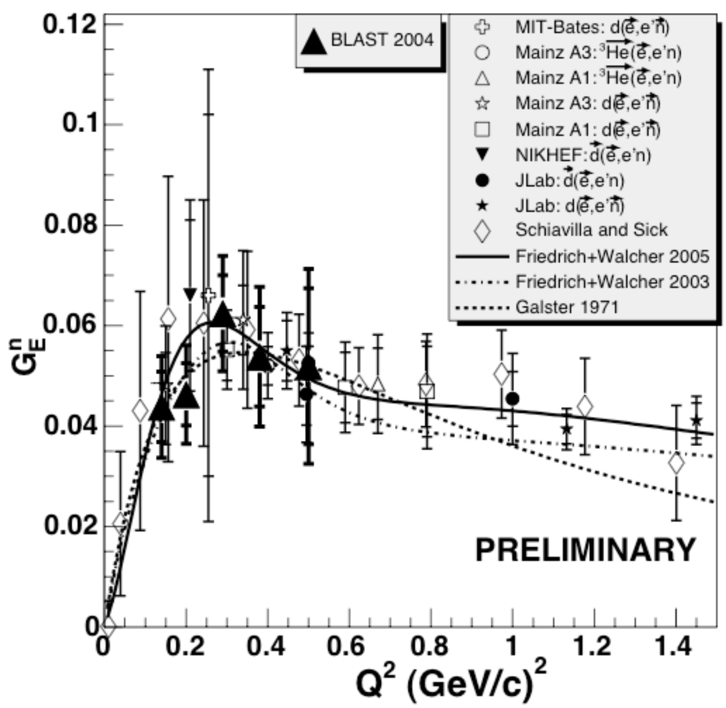

FIGURE 1. Electric form factor of the neutron from polarization experiments along with preliminary results from BLAST.

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